BARRIER MOVEMENT OPERATOR
HAVING OBSTRUCTION DETECTION

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The present invention relates to barrier movement
10 operators and particularly to barrier movement operators
having improved characteristics for detecting
obstructions to the movement of the barrier.

Barrier movement operators generally comprise an
electric motor coupled to a barrier and a controller
15 which responds to user input signals to selectively
energize the motor to move the barrier. The controller
may also respond to additional input signals, such as
those from photo-optic sensors sensing an opening over
which the barrier moves, to control motor energization.
20 For example, should a photo optic sensor detect an
obstruction present in the barrier opening, the
controller may respond by stopping and/or reversing
motor energization to stop and/or reverse barrier
movement. The controller may also respond to motor
25 speed representing signals by controlling motor
energization. Such may be used to stop and/or reverse
the movement of a barrier when the motor speed, which
represents the speed of movement of the barrier, falls
below a predetermined amount as might occur if the
30 barrier has contacted an obstruction to its movement.

Detecting contact by the barrier with an obstacle
by sensing the driving speed of the motor has certain
inherent difficulties. The barrier, barrier guide
system and the connection between the barrier and the
35 motor all have momentum and all exhibit some amount of
flexibility. When the leading edge of a barrier is
slowed, it takes time for the inertia of the various
parts to be overcome and for the slowing of the barrier

to be reflected back to the motor via the flexible (springy) interconnection. Through proper design and construction techniques, such systems have been successfully achieved for response times and contact
5   pressure thresholds to achieve safe operation. However, to achieve ever safer operation involving lower barrier contact forces and more rapid response times, new designs are needed.

     Motors for use with barrier movement operators are
10 generally constructed or selected to operate efficiently and exhibit a motor rotation rate (motor speed) to torque characteristic represented in Fig. 4. The normal forces on the barrier generally allow the operating motor speed between the marks labeled A and B on Fig. 4
15 resulting in a relatively flat slope of the speed versus torque characteristic. The "normal" motor having a characteristic as shown in Fig. 4 exhibits a change of motor RPM of approximately 20 RPM per inch-pound of required motor torque. Improvements in obstruction
20 contact times and reduction of obstruction contact forces is difficult with a motor having the characteristics of Fig. 4 because the change of motor RPM is small for the normal range of obstruction forces. A need exists for a motor which operates with a torque
25 to speed characteristic which is enhanced for rapid obstacle detection.

     Improvements in barrier contact obstacle detection may also be achieved by improvements in how sensed motor speed changes are interpreted. Existing barrier
30 movement systems include obstacle detection functions which compare currently measured motor speed with an obstacle indicating threshold. The obstacle indicating threshold generally consists of an expected motor speed minus a constant which defines how much additional speed
35 reduction represents an obstacle rather than a normal variation in operating speed. In some systems an

average speed is assumed for the entire movement between open and closed positions and when motor speed falls below the normal speed minus a fixed threshold an obstacle is assumed. In other systems a speed history
5 is determined for door movement by recording measured speeds at several (many) points along barrier travel. When the measured speed falls below the speed history for the same point in barrier travel minus a fixed threshold, an obstacle is assumed. Improvements are
10 needed in obstacle detection to permit fine control of speed changes which indicate an obstruction.

DESCRIPTION OF DRAWING

15   Fig. 1 shows a barrier movement system connected to a vertically moving garage door;

       Fig. 2 is a block diagram of the control apparatus for a barrier movement operator;
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       Fig. 3 illustrates circuitry for detecting motor rotation speed;

       Fig. 4 is a graph of motor rotation speed versus
25 required motor torque for existing induction A.C. motors;

       Fig. 5 is a graph of motor rotation speed versus required motor torque for enhanced A.C. induction motor
30 operation;

       Fig. 6 is a diagram of a modified A.C. voltage which may be used to power A.C. motors;

35   Fig. 7 is a graph representing motor speed and obstacle detection thresholds;

Figs. 8A and B represent the stator and field windings of an A.C. induction motor;

Figs. 9A and B represent the rotor of an A.C.
5 induction motor; and

Fig. 10 is a graph of motor torque versus motor current for normal and one enhanced induction A.C. motor.
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DESCRIPTION

Fig. 1 illustrates the use of a barrier movement operator 10 for vertically moving a garage door. It
15 should be understood that a barrier movement operator as described and claimed herein may be used to move other types of barrier such as gates, window shutters and the like. Barrier movement operator 10 includes a head unit 12 mounted within a garage 14. The head unit 12 is
20 mounted to the ceiling of the garage 14 and includes a rail 18 extending therefrom with a releasable trolley 20 attached having an arm 22 extending to a multiple paneled garage door 24 positioned for movement along a pair of door rails 26 and 28. The system includes a
25 hand-held transmitter unit 30 adapted to send signals to an antenna 32 positioned on the head unit 12 and coupled to a receiver as will appear hereinafter. A switch module 39 is mounted on a wall of the garage. The switch module 39 is connected to the head unit by a pair
30 os wires 39a and includes a command switch 39b. An optical emitter 42 is connected via a power and signal line 44 to the head unit. An optical detector 46 is connected via a wire 48 to the head unit 12.

As shown in Fig. 2, the garage door operator 10,
which includes the head unit 12 has a controller 70
which includes the antenna 32. The controller 70
includes a power supply 72 which receives alternating

5   current from an alternating current source, such as 110
volt AC, at a pair of conductors 132 and 134, and
converts the alternating current into DC which is fed
along a line 74 to a number of other elements in the
controller 70. The controller 70 includes and rf

10   receiver 80 coupled via a line 82 to supply demodulated
digital signals to a microcontroller 84. The
microcontroller 84 includes a non-volatile memory, which
non-volatile memory stores set points and other
customized digital data related to the operation of the

15   control unit. An obstacle detector 90, which comprises
the infrared emitter 42 and detector 46 is coupled via a
bus 92 (which comprises lines 44 and 48) to the
microcontroller. The obstacle detector bus 92 includes
lines 44 and 48. The wall switch 39 is connected to

20   supply signals to and is controlled by the
microcontroller. The microcontroller, in response to
switch closures, will send signals over a relay logic
line 102 to a relay logic module 104 which connects
power to an alternating current motor 106 having a power

25   take-off shaft 108. A tachometer 110 is connected to
shaft 108 and provides a tachometer signal on a
tachometer line 112 to the microcontroller 84. The
tachometer signal being indicative of the speed of
rotation of the motor. The tachometer 110 may comprise

30   an interrupter wheel represented at 115 (Fig. 3)
connected to rotate with the motor shaft 108. A light
source 128 and light receiver 127 detect rotation of the
shaft by detecting successive passings of a plurality of
light blocking apparatuses 117 and reporting to

35   controller 84 via communication path 112.
Microcontroller 84 can then determine current motor

speed by calculating the period between successive light
blockages. It should be mentioned that other means for
detecting rotation rate may also be employed such as a
cup shaped interrupter with equally spaced apertures
5 therethrough to successively block and pass light
between source 128 and detector 127. The signals on
conductor 112 from tachometer 110 may also be used to
identify the position of the barrier when used with a
pass point arrangement or position detector shown at
10 120, which operation is known in the art.

     The barrier movement operator of Fig. 1 begins to
move the barrier in response to a user pressing button
39B of wall control 39 or pressing a transmit button of
transmitter 30. Generally, when movement begins the
15 barrier is in the open or closed positions. When a
command to move the barrier is received, the barrier
driven toward the other limit. In the present
embodiment the controller 10 tracks the position of the
barrier in response to signals from tachometer 110 and
20 formulates operations based on that sensed position.
The controller also may respond to signals from optical
detector 90 representing a possible obstruction by
reversing the direction of a downwardly traveling
barrier.

25   The barrier movement operator of Fig. 1 also
responds to sensed information about the forces required
to move the barrier to control further barrier movement.
For example, as the barrier is moved, motor speed is
continuously checked as an indication of the forces
30 being required to move the barrier. Fig. 4 is a graph
of a normal motor showing motor rotation speed versus
motor output torque. As the forces required to move the
door increase the motor slows. The converse is also
true. The predictable nature of speed change versus
35 applied forces allows the motor speed to be used as an

indication of such things as the barrier contacting an obstruction.

Barrier movement operators have been constructed which respond to the motor speed falling below a fixed value by assuming that the barrier has contacted an obstruction and, accordingly, stop or reverse the travel of the barrier. More sophisticated systems have been designed which record measured motor speed at a number of barrier positions establish obstruction threshold histories for different barrier positions. Fig. 7 illustrates one such thresholding system in which 6 thresholds labeled 50, 52, 54, 56, 58 and 60 are shown. It should be mentioned that in Fig. 7 motor speed is represented by the period between successive light blockages from an interrupter wheel and as such higher on the graph of Fig. 7 represents lower motor speed. During movement of the barrier, a number of different motor speeds are sensed as represented by the measured speed line. Zones of interest are then selected and a value representing the minimum speed in each zone is recorded. In Fig. 7, the minimum speed in a first zone is represented at 51, a second at 53 and others at 55, 57, 59 and 61. A predetermined speed difference value may then be subtracted from each minimum speed to establish the overall threshold for the zone. The references 50, 52, 54, 56, 58 and 60 represent the per zone thresholds. After the zone thresholds have been learned (or updated) whenever measured speed falls below the zone threshold an obstruction is assumed and the barrier is stopped or reversed.

As shown in Fig. 7 each minimum threshold is a fixed amount different from the minimum speed in the zone as represented by the couplets 50-51, 52-53, 54-55 and 56-57. In the present embodiment, particular zones can be configured to be more sensitive than other zones. For example, the period (speed) difference between 57

and 56 is the same as the period (speed) difference between all other couplets toward the open representing left of the graph. Thus, all zones from 56-57 to the left are of substantially equal sensitivity. The zone

5 represented by the couplet 58-59 is more sensitive because less speed difference between the measured minimum 59 and the threshold 58 exists than between the other couplet to the left. As can be seen in Fig. 7 the most sensitive zone is near the closed position and

10 advantageously is placed within 18 inches of the closed position.

Other improvements to obstruction detection are made by the presently disclosed barrier movement system. Fig. 4 represents the speed versus torque characteristic

15 for a normal motor. As can be seen the slope of the line from A to B which represents a normal operating range, an increase of required torque of one ft. lb. results in a motor speed change of only about 12-13 RPM. This is a relatively small change to be rapidly

20 detected, particularly in the real environment as represented by the measured speed line of Fig. 7. Fig. 5 represents in the speed versus torque characteristic of a motor and its driving apparatus which is enhanced to improve motor speed change. The slope of the line

25 between points A1 and B1 on Fig. 5 results in a change of speed of approximately 47 to 48 RPM per inch-pound of torque thus making speed changes more easily detected.

A characteristic as shown in Fig. 5 can be achieved by producing a motor with the appropriate

30 parameters. Figs. 8A and 8B are views of a field winding/stator of an induction motor. Figs. 9A and 9B represent the induction rotor of such a motor. The rotor of an AC induction motor includes a plurality of ferris metal rotor lamination formed together into a

35 cylinder as represented at 62. The rotor laminations have a plurality of regularly spaced apertures which are

arranged to extend from one end of the rotor cylinder at
an angle as represented by 64. The apertures are filled
with an electrically conductive non-ferris metal such as
aluminum. Finally end rings 64 are formed at the ends

5   of the diagonal conductive lines 64 from non-ferris
electrical conductors to provide conductive paths
between the diagonals 64. Due to current induced by AC
applied to the field coils, magnetic fields are produced
in the rotor which cause rotation.

10   Normally motors are designed to provide very low
resistance in the cross paths 64 and the end rings 66
resulting in a characteristic as shown in Fig. 4. In
the present embodiment, however, the resistances have
been increased which results in an enhanced

15   characteristic as shown in Fig. 5. In a preferred
embodiment the resistance increase was produced by using
smaller than normal amounts of non-ferris metal for
conductors 64 and 66. The results could also be
achieved by fabricating the conductors 64 and 66 from

20   non-ferris material having greater internal resistance.
       In the above discussion the enhanced
characteristic (Fig. 5) was achieved during motor
fabrication or selection. Such can also be achieved by
selective coupling of incoming AC power to the motor

25   106. In Fig. 2 incoming AC power is connected to
conductor 132 and 134 which are in turn connected to a
power control circuit 114. An output of power control
circuit 114 is used to power the motor. Power control
circuit 114 selectively blocks portions of each cycle of

30   the incoming sinusoidal AC wave form shown in Fig. 6 to
the motor 106 via relay logic 104. The wave form of
Fig. 6 is achieved by a "light dimmer" circuit in power
control which is preset to pass a predetermined
percentage e.g., 60 percent of each sine wave cycle.

35   Energization of an AC induction motor with a wave form
shown in Fig. 6 results in a characteristic as shown in

Fig. 5. Greater control over the A.C. wave form applied to the motor 106 by using a power control circuit of the type described in U.S. Patent Application 10/622,214 filed 18 July 2003 which is connected to microcontroller

5 84 via a control line 118. Such greater control might include skipping entire cycles of applied A.C. Also the wave form of Fig. 6 may be reproduced using high frequency e.g., 1KHZ duty cycle control.

The preceding embodiment measured rotation speed

10 of the motor to detect possible obstructions because motor speed represents present torque requirements of the motor. (See Figs. 4 and 5) The current drawn by an induction A.C. motor also represents the present torque requirements of the motor. As the force requirements

15 increase so does the current applied to the motor. The motor current may be sensed by an optional current sensor 130 connected to the A.C. inputs of the relay logic 104. (Fig. 2) This relationship is shown in Fig. 10 as 203 for a "normal" motor and 201 for a motor

20 enhanced by the above described motor modifications and driving techniques. When motor current is sensed to detect possible obstructions, the enhanced characteristic 201 provides more rapid and certain obstruction detection.

25 While there has been illustrated and described particular embodiments of the present invention, it will be appreciated that numerous changes and modifications will occur to those skilled in the art, and it is intended in the appended claims to cover all those

30 changes and modifications which fall within the true spirit and scope of the present invention.